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New Frontiers of Varactor Harmonic Power Generation in the C-Band

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Gallium-arsenide "stacked" varactors employed in a frequency doubler and tripler have given 8- to 10-watt output at 4 and 6 GHz with efficiencies of 70 to 80 percent.

I. INTRODUCTION

We have designed and developed a new class of varactors that have been noteworthy beneficiaries of the techniques evolved for GaAs IMPATTs. In this paper we report the experimental results obtained from double-stacked diodes for frequency doubling (2 to 4 GHz), and double- and triple-stacked diodes for frequency tripling (2 to 6 GHz).

II. VARACTOR CONSTRUCTION

The power and efficiency sought in the present application (8- to 10-W output at 4 and 6 GHz with a minimum efficiency of 70 percent) dictate a low-loss, high-voltage varactor. These conflicting goals are best achieved by a series connection of two or more chips in a single package.[1] Using a Schottky-barrier GaAs chip, the power dissipation per chip is so small that a simple series stacking of one chip upon another is adequate, without heat sinks for any chip except the bottom one. This scheme is facilitated by using dice of typical C-band IMPATT design,[2] i.e., squat cylinders or truncated cones (0.2 mm in diameter by 0.08 mm tall, for example) in which the active area is that of the cylinder itself. The dice are thermocompression-bounded in "flip-chip" position, one on another, in a package with a diamond heat sink. The series combination not only increases power-handling capacity considerably, but it also alters the input and output impedances favorably.

The chips employed here were originally tested as IMPATTs, where they gave about 3 W at 10 to 12 percent efficiency in C-band.

As a douhle stack, these chips formed a varactor witb typical values of 7.5-pF zero-bias capacitance, 174-V hreakdown, and 0.65-ohm zero-hias resistance. In a triple stack, the varactor's values were typically 5.0 pF, 265 V, and 0.98 obm. The cutoff frequencies at breakdown are 300 GHz or greater.

III. THE 2- TO 4-GHz FREQUENCY DOUBLER

A coaxial embodiment of the douhler (see Fig. 1) has heen chosen to yield experimental flexihility. The diode is mounted at the center of a 30-cm, 50-ohm coaxial airline. A 4-GHz reentrant choke to hlock the output frequency from the input and a 2-GHz quarter-wave-long transformer to match the impedance constitute the input side. A quarter-wave 4-GHz transformer and a twin capacitor 2-GHz filter make the output side. The axis of tbe inner conductor is positioned at the axis of the outer conductor by radial pressure hetween the diode and a long, thin, spring-loaded polystyrene pin. The frequency doubling by the diode bas heen simulated on a digital computer, and the efficiencies and bandwidtb data are obtained together witb the impedance for hest results. Tbe correlation hetween the simulated results and experimental data is sbown in Fig. 2. The balf-dB bandwidtb at 4 GHz is approximately 300 MHz.

IV. THE 2.115- TO 6.345-GHz TRIPLER

A coaxial emhodiment with three limhs in a T configuration (see Fig. 3) for the input, output, and idler circuits has heen designed and constructed for tbe tripler circuit. Tbe diode is mounted along the axis

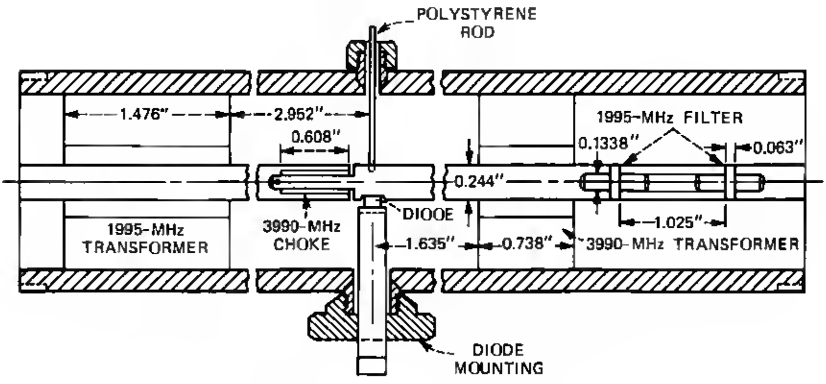

Fig. 1—Cross section of the 1995- to 3990-MHz doubler.

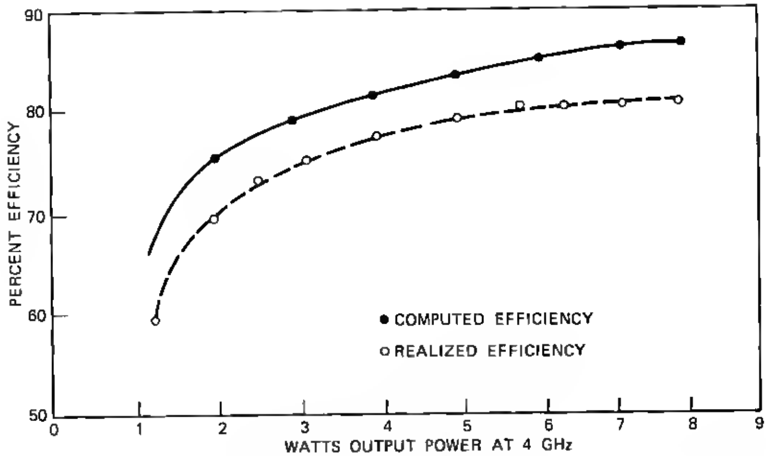

Fig. 2—Efficiency characteristics of the doubler, double stack 7.5 pF, 174V, 0.65 ohm.

of the T opposite the idler stub with the remaining two limbs for input and output sides. A 2.115-GHz quarter-wave transformer, a 4.23-GHz (idler frequency) choke, and a 6.345-GHz choke suitably located with respect to one another and the diode constitute the input side. A 2.115-GHz choke, a 6.345-GHz transformer, and twin-capacitor 4-GHz filter (also serving as a dc block) constitute the output. The idler circuit consists of a 0.53-pF capacitor (which also blocks the dc voltage because of average charge on the diode), a suitable length of the inner conductor, and a sliding short between the inside and outside conductors. The axis of the central conductor between the input and output sides is aligned with the axis of the outer conductor by opposing radial pressures between the stub and the diode. The positions of the various components in the tripler that can be computed agree well with the experimentally determined locations. Fine tuning is accomplished by four pin tuners, two on the idler stub and one each on the input and output limbs. The correlation between the simulated results obtained from a digital computer and the experimental data is shown in Fig. 4. The bandwidth that has been computed to be about 70 MHz at 6.345 GHz is experimentally measured at 0.5-dB points as 61.2 MHz at 8 W, 50.4 MHz at 7 W, 58.8 MHz at 6 W, and 66 MHz at 5 W for a *triple*-stacked varactor. This varactor is extremely resilient to the extent that no damage occurs by gross mistuning at 10 W. The *double*-stacked varactor has yielded 10 W but has been occasionally damaged while tuning, probably because of excessive avalanching.

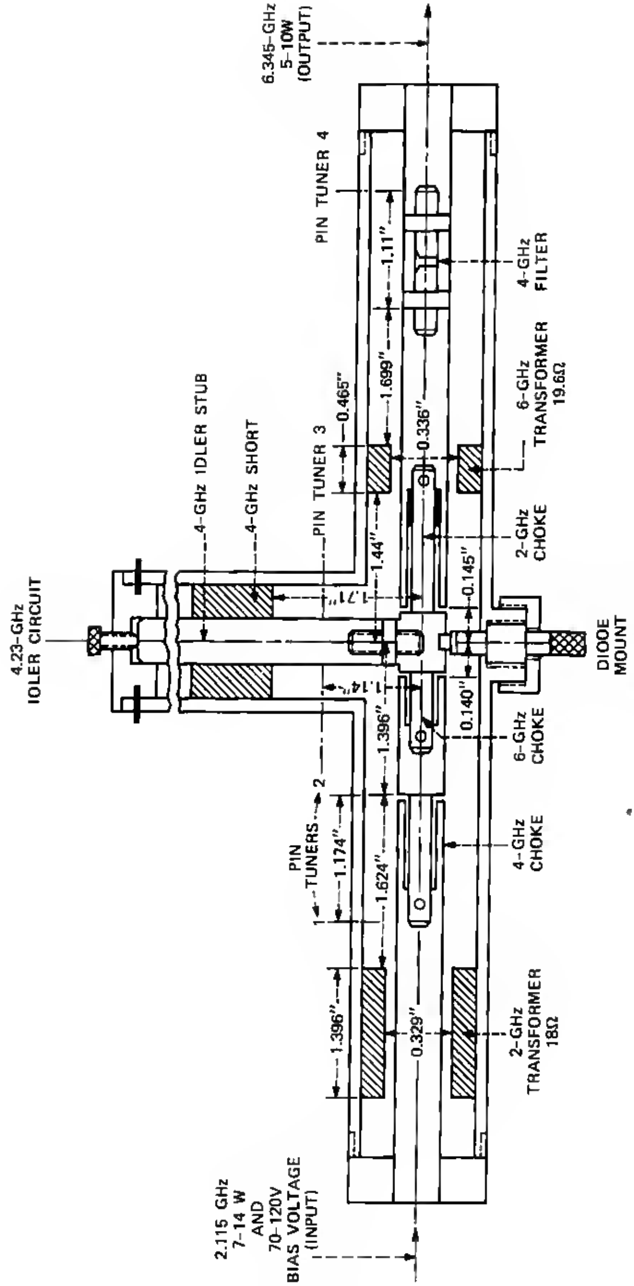

Fig. 3—Assembly of tripler.

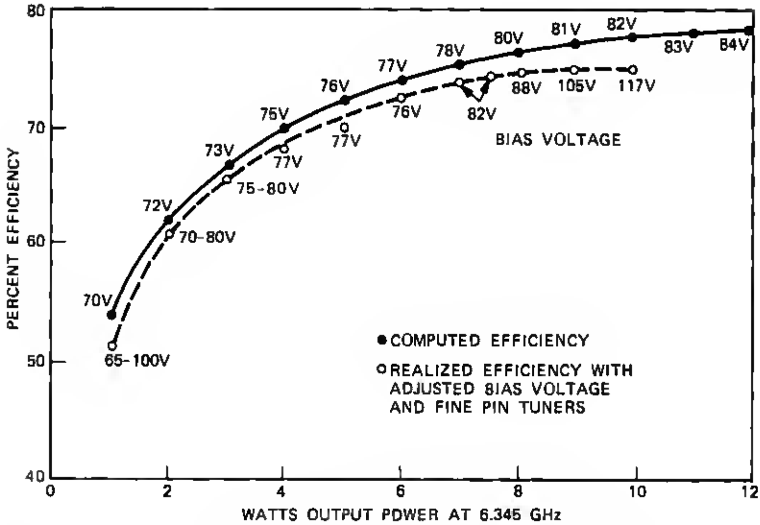

Fig. 4—Efficiency characteristics of the tripler, triple stack 5 pF, 262V, 0.97 ohm.

V. CONCLUSIONS

Both high power and high efficiency that approach the theoretical limit for GaAs diodes of this design may be simultaneously achieved by proper design of the varactors. The good control in doping density, the use of nonohmic back contacts, and a diamond-based heat sink that permits a tolerable temperature rise of the most thermally isolated chip in a stacked varactor, make these new varactors good contenders for microwave power by frequency multiplication.

REFERENCES

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